

Peer Review

Wind Energy research programme

Aart van der Pal
Director ECN Wind Energy

Peter Eecen
R&D Manager – ECN Wind Energy



Vision

ECN Wind Energy as a leading institute in:

Innovative Solutions for Offshore Wind Power Plants

- Reduce cost of energy of offshore wind power plants
- World leading innovative products and solutions
- Critical success factors are our world leading facilities
- Beyond state of the art wind farm services



World leader R&D institute on Innovative Solutions for Offshore Wind Power Plants

In 2020 ECN Wind Energy is world leader R&D institute on:

Innovative Products and Solutions for Offshore Wind Power Plants

Resulting in:

- Reduction of cost of energy by 40%
- Assisting industry by state-of-the-art wind farm services
- More competitive Dutch industry by implementing innovations

Differentiating factors:

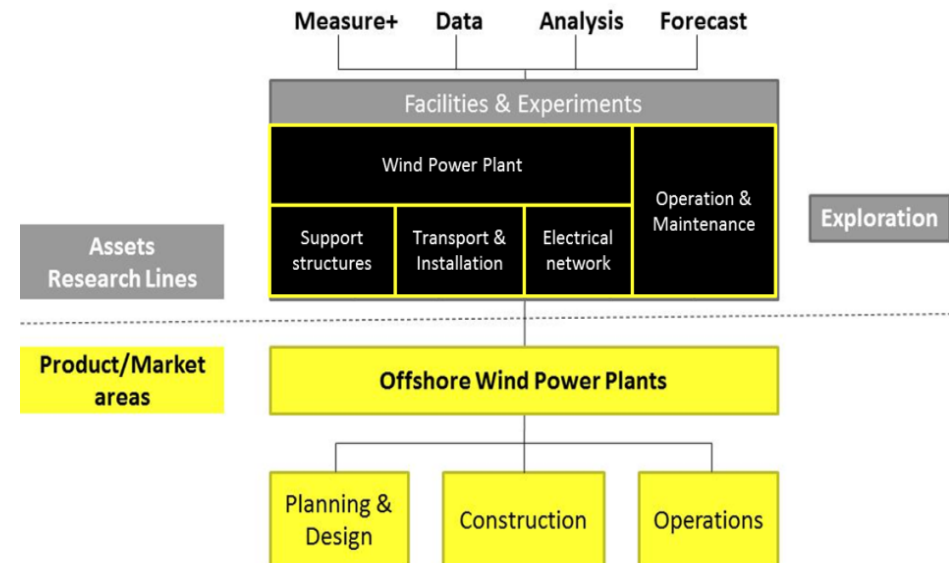
- ECN world leading facilities onshore and offshore
- In-depth know knowledge on key-factors for offshore wind power

Main Characteristics ECN Wind Energy in 2020

- Around 50 specialists in offshore wind energy
- Brings pre-competitive R&D to Industrial application (TRL 3 to TRL 9)
- Facilitates Dutch industry in the wind energy market
- Operates 2 test facilities (Wieringermeer and Groningen)
- Operates 4 offshore measurement masts
- R&D largely funded from TKI, H2020
- B2B R&D programme
- Close collaboration with universities on TRL1 to TRL 4

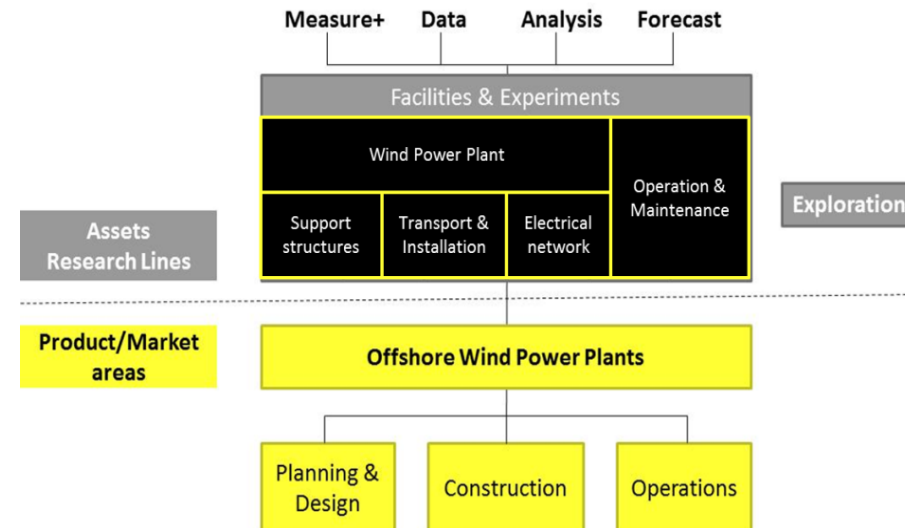
- **The ECN-Wind R&D focuses completely on offshore wind power plants. The R&D strategy is fully aligned with the Dutch Energy Agreement target for reduction of Cost of Energy to 10 €/kWh.**
- ECN R&D targets contribute to TKI Wind op Zee R&D targets
ECN has structured its R&D lines along the TKI R&D lines
- Changes in strategic R&D:
 - Intensified R&D on
 - support structures
 - transport, installation and logistics
 - R&D is focused to create services for the Dutch offshore industry.

Programme structure



Aims of the PMCs

1. Supporting Dutch offshore industry by providing cost-effective support structures
2. Reducing COE by integrated wind farm design approach
3. Minimise Costs by Optimising Electrical Network
4. Support the Dutch offshore industry in expanding their leading position
5. Implementing operational excellence to minimize O&M costs
6. PMC 6 has been terminated from 2015
7. ECN is the preferred partner for measurements on offshore wind farms; Validation is an essential differentiating factor for the ECN activities



ECN's onderzoek en ontwikkeling binnen de topsector Energie

Externe ontwikkelingen

Ontwikkeling offshore windparken in Energieakkoord

- In het Nederlandse Energieakkoord zijn afspraken gemaakt voor de implementatie van duurzame energie tot 2023. Windenergie (met name offshore windenergie) speelt een belangrijke rol. Het R&D programma van ECN is gericht op het verder verlagen van de kostprijs.

Grote Nederlandse offshore sector

- De ontwikkeling, bouw en bedrijfsvoering van offshore windparken vereist een grote inspanning van de offshore industrie. De Nederlandse offshore industrie wordt door ECN Windenergie ondersteund en is betrokken bij 80% van alle offshore windparken in Noordwest Europa.

Beheer en onderhoud

- Het beheer en onderhoud van de offshore windparken levert grote werkgelegenheid op. Nederlandse partijen ontwikkelen concepten en diensten om de windparken efficiënt te onderhouden. ECN is wereldwijd leidend in het onderzoek naar optimalisatie en kostenreductie bij onderhoud van offshore windparken.

In het Energieakkoord is een implementatie van offshore windenergie afgesproken tot 2020. In de tabel is de geplande bouw van offshore windparken aangegeven. Een vereiste voor deze implementatie is de reductie van kosten van energie met 40% in 2020.

Tender	Capacity (in MW)	Operational in
2015	700	2019
2016	700	2020
2017	700	2021
2018	700	2022
2019	700	2023

Highlights ECN onderzoek en ontwikkeling 2014

Met name in geïntegreerde windpark technologie heeft ECN succes geboekt

Active Wake Control

- ECN heeft patenten op het gebied van windparkregelingen: het gaat er niet alleen om dat individuele turbines zoveel mogelijk produceren binnen een windpark, het doel is dat het windpark als geheel optimaal produceert. Hiertoe worden de turbines door een parkregelaar gestuurd zodat het totale windpark optimaal produceert. Dit levert 1 tot 3% meer opbrengsten voor grote offshore windparken.

O&M Concept

- ECN heeft sinds 10 jaar een toonaangevend onderzoeksprogramma op het gebied van beheer en onderhoud, ook operation and maintenance O&M genoemd. ECN heeft een onderhoudsconcept ontwikkeld bestaande uit diverse onderdelen dat in 2015 in een groot offshore windpark zal worden gedemonstreerd.

Geavanceerde Technologie

- ECN heeft naam gemaakt met de ontwikkeling van geavanceerde technologie. Voorbeelden zijn:
 - Ontwerpen van innovatieve bladen voor megaturbines
 - Ontwerpen voor ondersteuningsconstructies
 - Innovatieve onderhoudsconcepten
 - Toevoegingen aan bladen om prestaties te verhogen
 - Geavanceerde controllers (Individual pitch + Typhoon)
 Deze innovaties leiden tot kostenbesparingen en vergroten de productie.

Dutch Industry and ECN in European Offshore Wind Farms



Prinses Amalia		2008	120							
Inner Dowsing		2009	97							
Lynn		2009	97							
Rhyl Flats		2009	90							
Horns Rev II		2009	209							
Robin Rigg		2009	180							
Gunfleet Sands		2009	173							
Alpha Ventus		2010	60							
Belwind I		2010	165							
Rødsand II		2010	207							
BARD 1		2010	400							
Thanet		2010	300							
Walney I		2010	184							
Greater Gabbard		2010	504							
EnBW Baltic I		2010	630							
Ormonde		2011	150							
Sheringham Shoal		2011	317							
Walney II		2011	184							
London Array		2011	185							
Thornton Bank II		2012	48							
Anholt		2013	111							
Thornton Bank III		2013	400							
Lincs		2013	270							
Borkum West II		2014	200							

Innovative solutions to lower the cost of energy



ECN innovations and services: Cutting Edge Technology



Innovative solutions
to lower the cost of energy

Measurements & Validation
Wind conditions
Turbine/Farm performance

Innovative turbines
Integrated Design
Large, Reliable, Cost effective
Innovative concepts

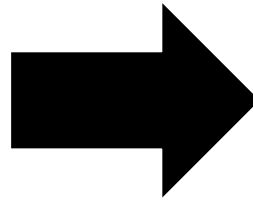
**Improved Installation,
Operation and Maintenance**
Strategies
Vessels and special equipment

Production Optimisation
Farm / Turbine performance
Active Wake Control
Availability



Teaming up within the Industry

Changes in R&D Focus



1. Turbine performance improvement
2. Component analysis
3. Software based analysis
4. Onshore development
5. Individual phase analysis

1. Wind farm performance improvement
2. Component analysis for wind farms
3. Simulated & Measured improvement
4. Offshore development
5. Integrated Phase Approach

ECN innovations and services: Choices made



- Focus on offshore wind farms – all activities aiming at onshore stopped
- No longer providing design tools to industry
- Strict Criterium: develop technology to create unique services
- Scale wind farm removed
- Other competences researchers
- Etc.

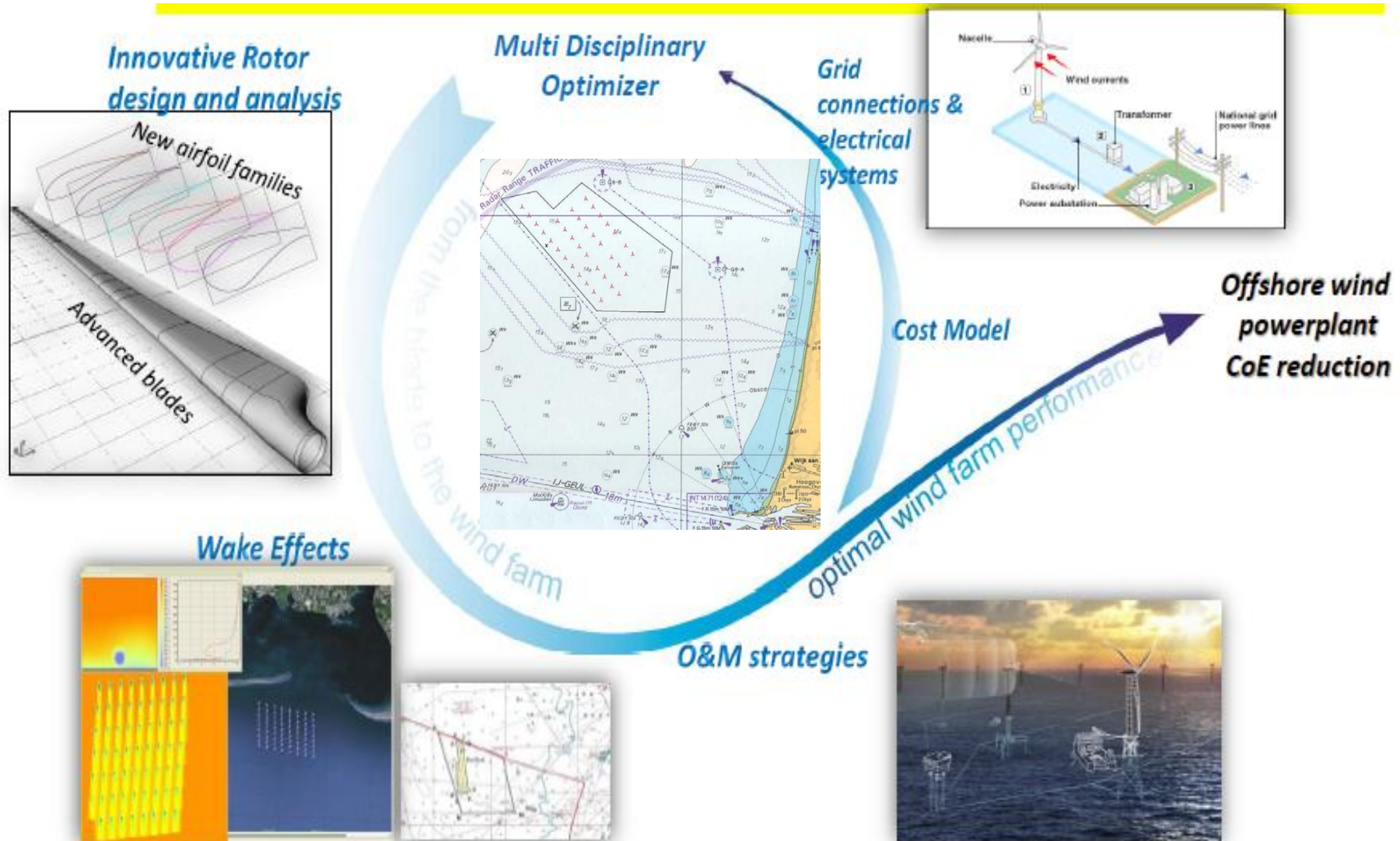
Unique design tools

- ECN has initiated several ground-breaking developments in design tool development.

Highlights:

- RFOIL – design of airfoils (used in >95% all turbines)
- FOCUS (PHATAS) - Integral design wind turbine
- Aerodynamic modelling in Aeromodule – blade design
- EeFarm – electrical infrastructure
- FarmFlow – wake modelling offshore wind farm
- O&M Tool – O&M modelling (used for 85% offshore windfarms)
- ECNInstall – Installation modelling
- The methods and the validation results are published and are incorporated by companies.

Fully Integrated wind farm design, 'Roadmap for the Future'



Case study 9

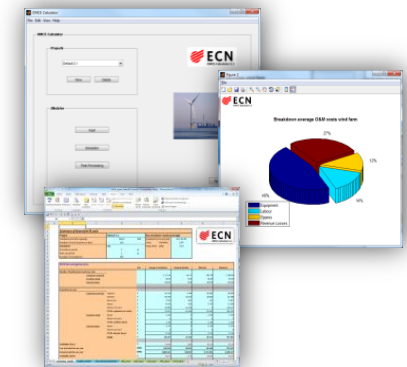
O&M System



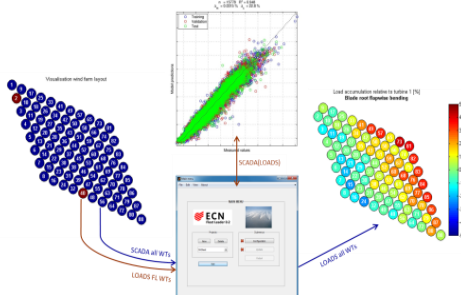
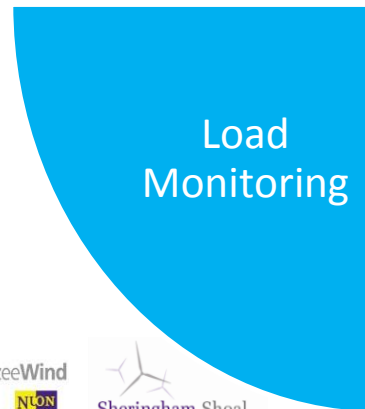
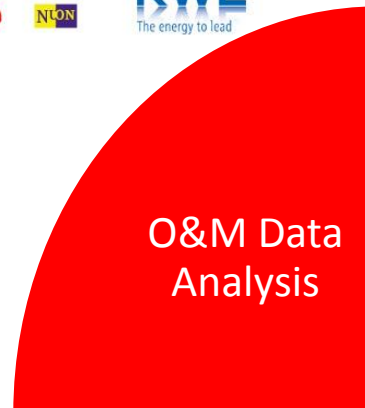
The ECN O&M Tool has been used by over 35 parties
>80% European offshore wind farms



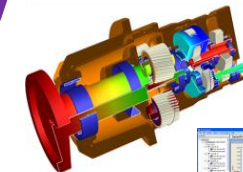
EventList & DataProcessor



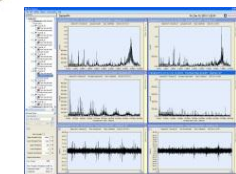
ECN O&M Calculator



FleetLeader



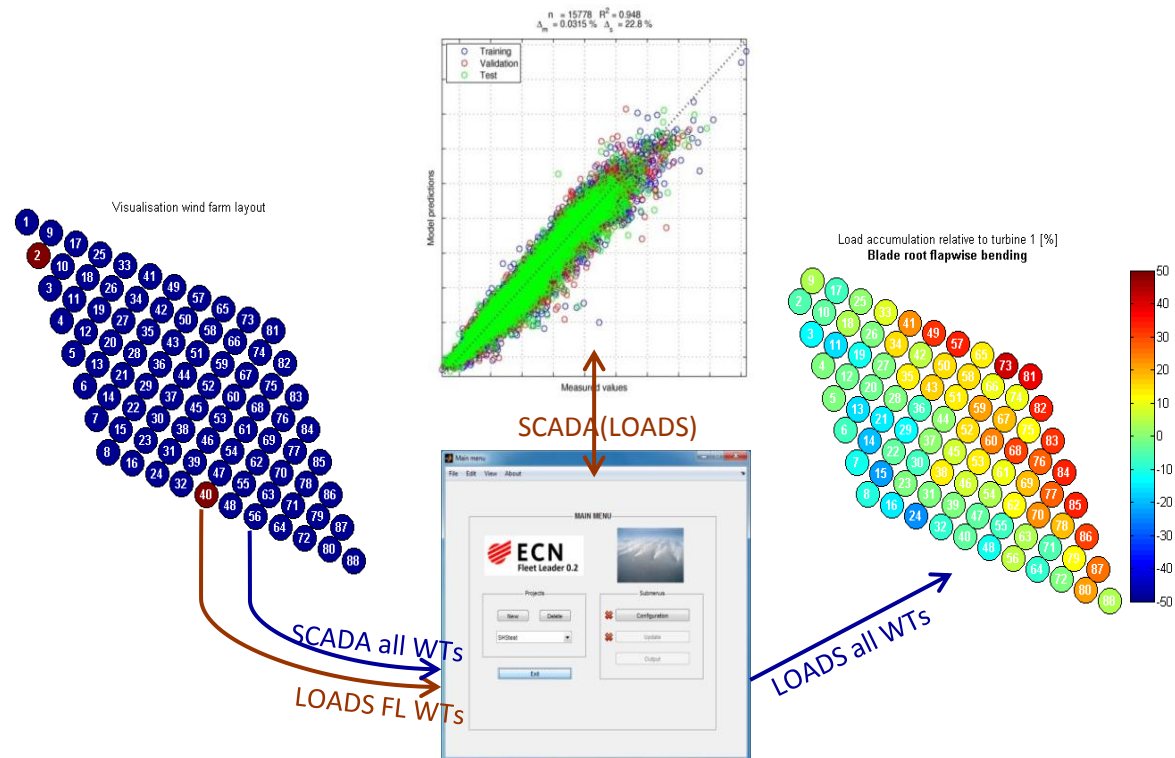
3rd party systems



Fleet Leader concept

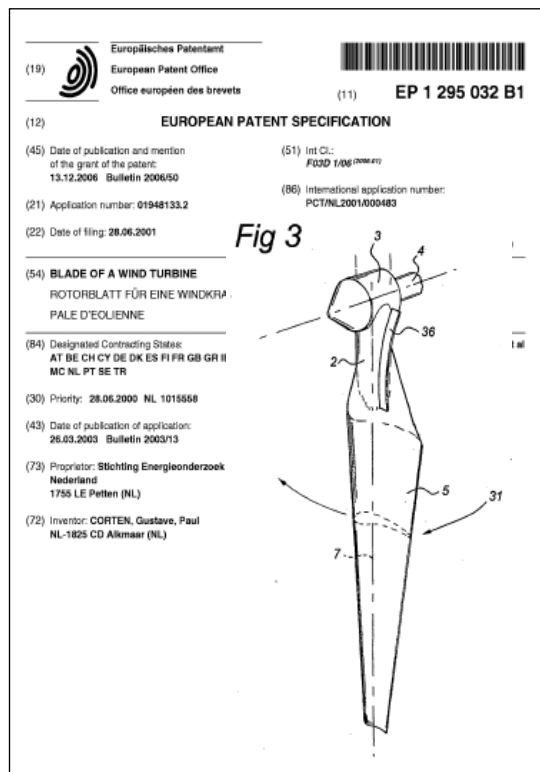
System to monitor load history of all wind turbines at low costs

- Few WT's equipped with load measurements (Fleet Leaders)
- Relations between measured loads and SCADA
- Load estimated at all WT's



Blade Root Spoiler

- ECN **Blade Root Spoiler** patented technology improves the performance of the root region of the blade and in this way, the wind turbine performance.



Case study 11

Floating wind turbine design



- Semi-Submersible
- Special mooring 50 to 100m depts, conventional system for > 100m
- No active ballasting needed
- No braces: easy fabrication & no fatigue sensitive details with limited access
- Stable when afloat: installation with tugs on pre-laid mooring system
- Specific design can be adapted to site conditions and usage: meteorology mast, substation etc.
- Customised and dedicated floating wind turbine controller



Unique Facilities

- ECN has develop a test site in the Wieringermeer

Highlights EWTW:

- Prototype locations that are 100% occupied + turbines are replaced (!)
locations are used for several turbines
 - Research turbines – the facility was unique and still is. More than 20
European research consortia have performed the experiments at EWTW
 - Scale wind farm – used to maximum impact and removed
-
- ECN operates offshore measurement masts

LIDAR experiments at ECN Wind Turbine test site



Validation

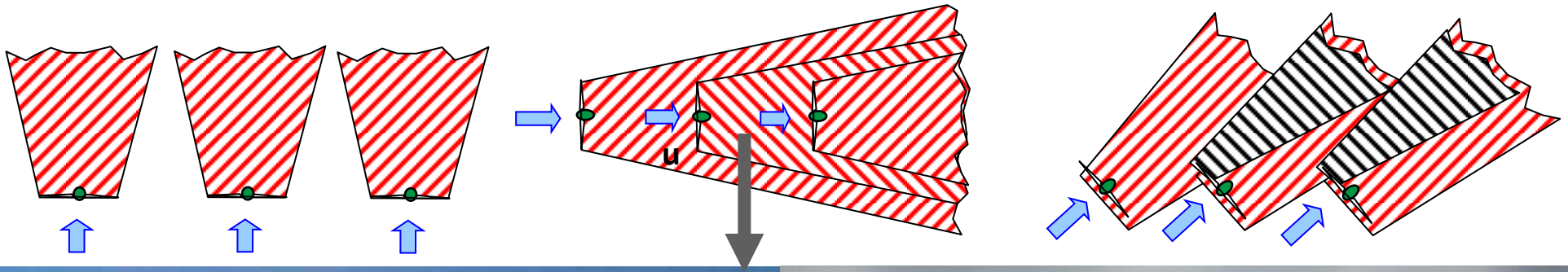
- Large aerodynamic validation experiments
- Largest wind tunnel Europe
- ECN coordinator
- Data available for and investigated by consortium with partners from all over the world



ECN Wind farm Control



Increasing efficiency by 0.5 to 5%

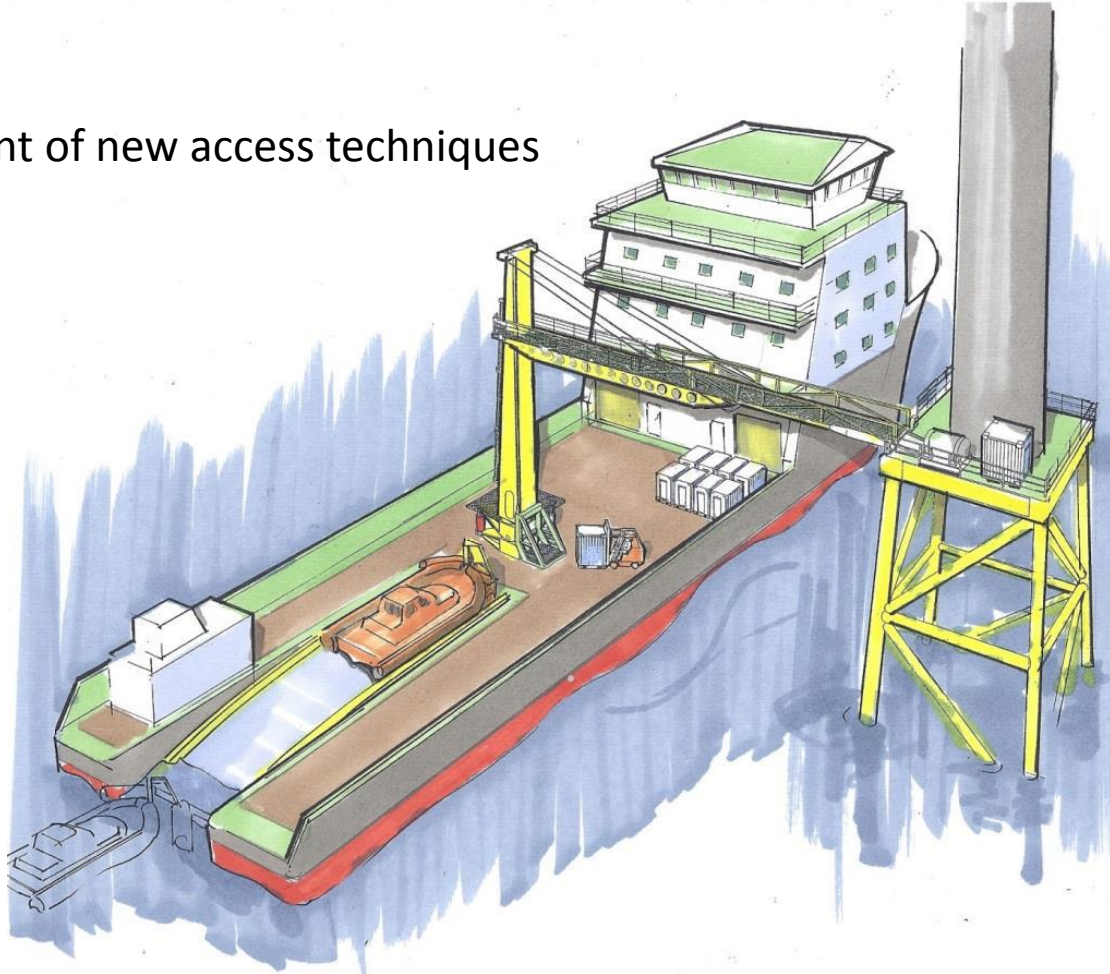


Total farm efficiency increase from 0.5 to 5%

Example with Dutch offshore industry: Z-Bridge project



Development of new access techniques



Vraagsturing / Demand driven

- Sector (industry and R&D sector) organised by ‘Innovatiecontract WoZ’. Leading for choices EZS
- Yearly, ECN R&D programme coordinated with TKI WoZ
- Tenders aim at higher TRL-levels – In addition, research must lead to reduction SDE+ voor 2023
- Horizon2020 aims at demonstration – industry is leading
- Little support and opportunity for low-TRL research:
 - Projects in collaboration with universities: STW projects
 - Innovation-tender: limited budget

Ready for the future? Impact of ECN Wind after 2020

Vision 2020 - 2030

- In Wind Energy Technology, strong development and implementation of innovations will be required after 2020. Innovations are driven by further requirements to reduce Cost of Energy in order to make wind energy subsidy free.
- In the period 2020-2030 ECN Wind contributes to:
 - Further **increase of scale** – turbines will grow to 15+MW turbines.
 - Development of **floating offshore wind power** with CoE comparable to bottom-fixed wind turbines.
 - **Operational excellence** is growing in importance – dedicated monitoring is applied to improve asset management.
 - Innovations in **control** – both on turbine level as on wind farm level to further improve operational performance.
 - Innovations in **measurement technology** – both aiming at performance verification (advanced LiDAR) as well as condition monitoring.
 - The **vertical axis** floating 15+MW wind turbines will evolve, requiring extensive innovations
 - Connecting large offshore wind power to the national grids including implementation of **storage technology** is a challenge that is addressed from 2020 to 2030.
 - The Dutch offshore industry will implement further innovations in installation, production and shipping in order to remain competitive.
 - **Recycling, repowering and life-extensions** will become important R&D topics.
 - Integral approach towards combinations of wind power, tidal power and biomass production in order to obtain optimal synergy.

Competences

- ECN Wind builds upon integral wind farm design
- Crucial ingredients for the integral approach is in-depth knowledge on
 - Design of wind turbines
 - Design of support structures
 - Design of electrical infrastructure
 - Operation and maintenance
 - Measurements and experiments
- ECN is actively engaged in operational excellence and applies its technology to offshore wind farms.
- Advanced measurement and monitoring technology is developed and applied to offshore wind farms
- Validation is enabling differentiating factor for cutting edge technology

Partnerships

- ECN Wind is active in technology partnerships with
 - Dutch and International companies – implementing and demonstrating the ECN technology
 - Dutch and international knowledge centres – collaborating in large international R&D programmes
- These partnerships facilitate successful knowledge transfer to further reduce cost of energy of offshore wind power.

Pre-competitive R&D

- ECN Wind will develop and patent new technology. With industry these innovations are developed to higher TRL and implemented.

Summary

- ECN Wind Energy has impact in offshore wind power, knowledge of wind turbines is key to assist industry in offshore wind
- The goals of the R&D Programme have been and are being reached: ECN Wind Energy technology is implemented
- An R&D programme is defined in collaboration with Dutch (TKI) and European (EERA TPWind) industry on
 - short term, medium term and long term
- Funding is at the edge, has significantly reduced over the last years.
- Funding is lacking for
 - Low TRL research / Underpinning research
 - EZ/RVO requests to assist in handelsmissies/kennismissies/workshops (knowledge transfer)
 - Contribution to standardization (IEC, MEASNET) and international collaboration (IEA)
- Collaboration with industry, institutes, and universities is key.



ECN

Your energy. Our passion.

Thank you very much for your attention

Peter Eecen

eeecen@ecn.nl

R&D Manager Wind Energy

Aart van der Pal

a.vanderpal@ecn.nl

Unit Director Wind Energy